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DESIGNING NEW CONCEPTS FOR HOUSEHOLD APPLIANCE WITH THE HELP OF TRIZ

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Abstract

This paper presents a case study of the application of TRIZ in an industrial development project. The study focusses on the TRIZ method “Trends of Engineering System Evolution” to develop innovative ideas for future household appliance. The paper starts with an introduction of TRIZ and the fundamentals of Trends of Engineering System Evolution. Building up on this theory the application of the method follows a five-step approach. First, four Main Parameters of Value are identified: Noise, Drying Result, Water Consumption, and Speed. In the second and third step, these parameters are evaluated and allocated on the Technology-S-Curve. Finally, in the fourth and fifth step TRIZ trends and sub-trends are used to develop ideas for household appliance based on their position on the S-Curve. Overall 44 ideas were developed. The result part presents three conceptual ideas. The paper closes with a conclusion of the project work and results. Main findings are: TRIZ trends are applicable in industrial project work, internal knowledge is needed for detailed application, and time-consuming application.

Keywords: Case study, Design methods, Innovation, TRIZ, Trends of Engineering System Evolution

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1 INTRODUCTION

1.1 Predictions for future systems

"The evolution of all technical systems is governed by objective laws."
Genrich Saulowitsch Altschuller, the author of this axiom (Shulyak, 1997, p. 15), was a forward thinker and founder of the innovation-methodology TRIZ - *theory of inventive problem solving*. With this quote, he claims that the development of technical systems follows specific processes and is not random. From this two questions arise. Firstly, what are these processes? And secondly, are these processes steerable? Or to put it in other words: is it possible to predict the future for any technical system? To a certain extent, in this paper we answer this question with yes. In particular TRIZ methods, like the *Trend of Engineering Systems Evolution* (TESE), allow such trend-forecasting. Additionally, there are many well-known methods to generate or structure ideas or innovations, such as *Brainstorming* or *Mind-Maps* (Jones *et al.*, 2001; McEntire, 2004). Besides, there are many other methods to develop new generation products such as *Product Generation Engineering* (Albers et al., 2016). Because these methods are well-elaborated, this paper focuses on TRIZ within an industrial project, resulting in a case study. The results of the applied TRIZ methods show that they are suitable for the problem of developing future products by means of generating new ideas.
Following Pahl and Beitz (1996), we understand a technical system as a system that is able to perform a transformation of energy, material or signal. Technical systems are running even faster through development- and usage-cycles (Souchkov, 2014; Jänsch, 2006). This shows how important it is for manufacturers to identify trends, thus to react quickly and to set themselves apart from the competition. This paper shows how to apply the TRIZ method TESE to identify trends and to develop new concepts. The project behind the paper cooperated with a big household appliance manufacturer. The aim of this project was to develop new concepts for household appliances with the help of TRIZ.
The paper is divided in five parts. In the first part, we present the purpose of the paper and the fundamentals of TRIZ. In the second part, we describe the basics of TRIZ' TESE. This method provides the framework of the case study presented. In the third part, we present the application of TESE in an industrial development project. In the fourth, part we present selected results of our case study. Finally, in the fifth part, we summarise and conclude the case study presented.

1.2 The fundamentals of TRIZ

TRIZ is a directed idea-finding-methodology which has its origin in the 1960's in Russia. TRIZ is the acronym for the Cyrillic expression *Teoriya Resheniya Izobratatelskih Zadach* which means *Theory of Inventive Problem Solving* (TIPS). (Herb et al., 2000) The theory is based on an investigation of 200,000 patents by Altschuller after World War II (Shulyak, 1997). He generated the first basic TRIZ tools, like the *Technical Contradictions* or the *Physical Contradictions*. The *Technical Contradictions* contain the *40 Innovative Principles* and the *39 Technical Parameters* (Lindemann, 2014). These principles are probably the most known and practised TRIZ tool which helps to overcome any contradiction, without having to compromise (McEntire, 2004; Shulyak, 1997). TRIZ has also been utilized in many big companies to solve problems for their product, such as Boeing, Samsung or M&M Mars (Souchkov, 2015).

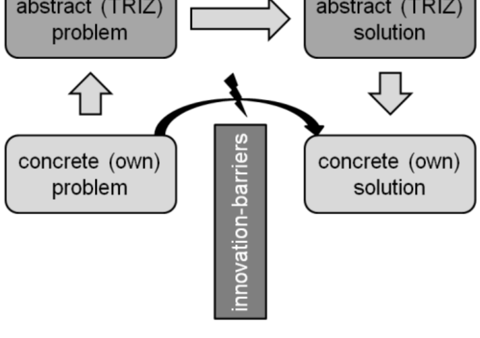

Figure 1. TRIZ approach: Overcoming innovation-barriers by abstracting problems according to Souchkov (2015)

TRIZ is based on three theses which were derived by Altschuller (Münzberg et al., 2014):

1. The development of technical systems follows specific patterns.
2. It is necessary to overcome contradictions during processes of inventing.
3. A small amount of solution principles underlies a great amount of inventions.

The second thesis presents the following procedure to solution finding, if mind-barriers hold up. To solve a concrete problem, it is at first necessary to abstract the problem. At the abstract level, TRIZ tools provide abstract solutions which could be transferred to the concrete level (Souchkov, 2014). The transfer from the abstract solution to the concrete solution is the last step and the most important. But it also is very challenging. However, this step leads directly to the disintegration of the problem. Figure 1 summarises this approach. The next part introduces the method *Trend of Engineering Systems Evolution* as a helpful method for this step.

2 THEORETICAL PROBLEM STATEMENT - NEW CONCEPT FOR FUTURE PRODUCT WITH THE HELP OF TRIZ METHODS

2.1 Motivation and Roadmap

The goal of this paper is to show the useful application of TRIZ in an industrial product development project to find solutions for a worldwide acting company. TRIZ is in the position, to find solutions for problems of a product or to overcome concerns of customers. Innovations could be trigger for new customers to buy the product. In our case, we followed a five-step approach:

- Step 1: *MPV-Analysis* (MPV - Main Parameter of Value): Identification of parameters to reflect the customers' needs and dissatisfactions.
- Step 2: Evaluation of MPVs by use of metrics: How did the system behave in the past?
- Step 3: *S-Curve-Analysis*: Identification of system life-phase based on MPVs.
- Step 4: Identification of useful sub-trends.
- Step 5: Application of the identified sub-trends: Development of new concepts for system improving the existing MPVs.

By applying this approach, the paper shows the potential of the trend-forecast method TESE in an industrial context.

2.2 Main Parameters of Value

Generating revenue and maximizing profit is the aim of every company. Innovations help to get the most out of business growth with the existing resources. The customers, as user of the product, take the centre stage (Litvin, 2011). Therefore, a company has to make sure, for which characteristics of the product the customer is willing to spend his money. Those characteristics are called Main Parameters of Value - MPVs (Litvin, 2011). The literal definition of MPV is: Key attribute/outcome of a product/service that is hereto unsatisfied and important to the purchase decision process. Following these categorisations, MPVs are important and unsatisfied attributes of a system for the customer. They are technical, physical, chemical or geometrical parameters of a system (Ikovenko, 2008a).

2.3 S-Curve Analysis

The *Trend of S-Curve Evolution* is the first trend within the method TESE. Technical systems evolve along *S-Curves* over time (Altschuller, 1979). They provide information in which phase of its development a technical system, or rather their MPVs are (Nähler and Gronauer, 2015). *S-Curves* also give proposals which lead to improvements of the technical system or rather their MPVs (Adunka, 2013).

The history of *S-Curves* started in the 19th century. In 1938 the Belgian mathematic Pierre Verhulst set a mathematical equation which outlines the growth of a population, for example the growth of bacteria. Over time, a closed up culture of bacteria describes the famous bell-curve over time. Cumulative the result is an S-shaped curve. (Kucharavy and Guio, 2007)

Every technical system evolves along *S-Curve*s. Further, each *S-Curve* is divided into four phases, so called life-phases or life-stages, in which a technical system resides within a certain time. The four phases are: Birth, Infancy Growth, Maturity, and Retirement. Figure 2 depicts the four phases of *S-Curves*. The specification of the MPV is plotted over time. A transition point between phase 1 and 2 marks the market entrance of the system.

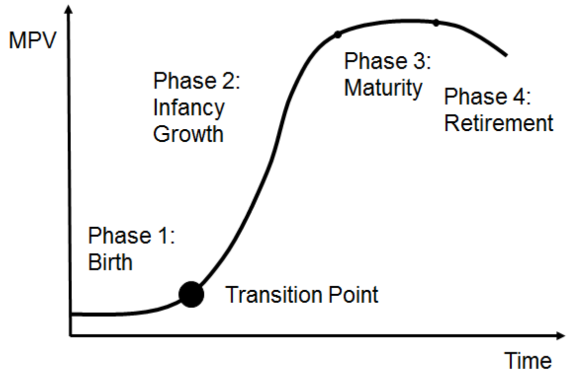

Figure 2. An S-Curve with the four life-phases for technical systems (own figure)

We used different metrics to allocate our MPVs to its life-phases. These metrics help to identify the behaviour of a MPV over time. Altschuller (1979) proposed the following four metrics: *Performance*, *Level of Invention, Number of Inventions* and *Profitability*. Each metric has its own course and is further subdivided into four phases, correlative to the four phases of *S-Curve*s. Figure 3 gives an overview over the four metrics and their courses, as well of the *S-Curve*.

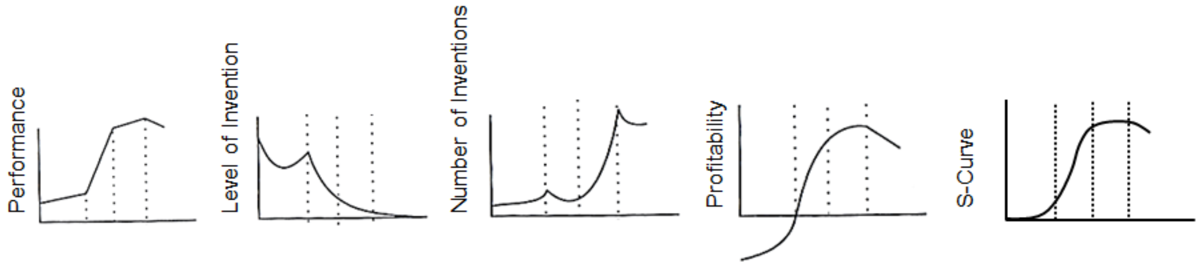

Figure 3. The four metrics and their courses by Altschuller, which help to allocate MPVs on S-Curves according to Terninko et al. (1996)

Every metric describes the MPV from a different viewpoint. Each one has its difficulties, advantages and disadvantages. The metrics are explained on the example of "fuel consumption":

- The metric *Performance* is the easiest to describe because it often is a physically measurable value (Mann, 1999). The value "litre per 100 kilometres" is suitable to describe the fuel consumption of a car. Old brochures, manuals or databases are a good basis to identify older values which are easy accessible. After plotting the data over time and comparing it with the course of *Performance*, the life phase of the MPV is identified.
- The metrics *Level of Invention* and *Number of Inventions* are more time-intensive because it is necessary to perform a patent-analysis (Mann, 1999). A research at the online platform of the European Patent Office (2016) gives 41,178 entries for the term "fuel consumption". The discovered data are compared with the courses of the metrics to find the current phase of the MPV.
- The metric *Profitability* is very difficult to describe for a private individual (Mann, 1999). However, it is simpler for a company because it has insights to its own profit structure. Inventions to improve the fuel consumption of a car should be investigated for their *Profitability*. Again, the evaluation over time and comparison with the whole course reveals the allocation to a phase for the MPV.

After evaluating all available metrics, it is possible to draw a conclusion from the phase of each metric to the phase on an *S-Curve* for the MPV. Because of the congruence of all four phases of the metrics (e.g. each in phase 2), it directly leads to the corresponding phase on the *S-Curve* (also phase 2).

2.4 TESE and its main- and sub-trends

For the development of a system it is important to know the specific S-Curve phase of MPVs. This gives information about how this parameter behaved in the past and will behave in the future (International TRIZ Association, 2014). The TRIZ method TESE helps to make those. With this the application of

TESE has two advantages. Firstly, this bears a mighty potential using this knowledge for designing new products. Secondly, TESE both identifies problems and solves them.
The TRIZ method *Trends of Engineering Systems Evolution* (TESE) also helps in general to get an advantage through innovations like a new design of a product (Terninko et al., 1996). TESE considers itself as a trend-research method and is therefore a suitable tool, to derive new concepts for technical systems.
TESE evolved historically over time, from old Altschuller's trends to modern type. Figure 4 shows the hierarchy of TESE which is now taught by the International TRIZ Association (2014). As shown above, another important method is the MPV-Analysis. It is classified before the *S-Curve-Analysis* because it provides information which parameters of the product are important for the customer and should undergo an *S-Curve-Analysis*. (Ikovenko, 2008b)

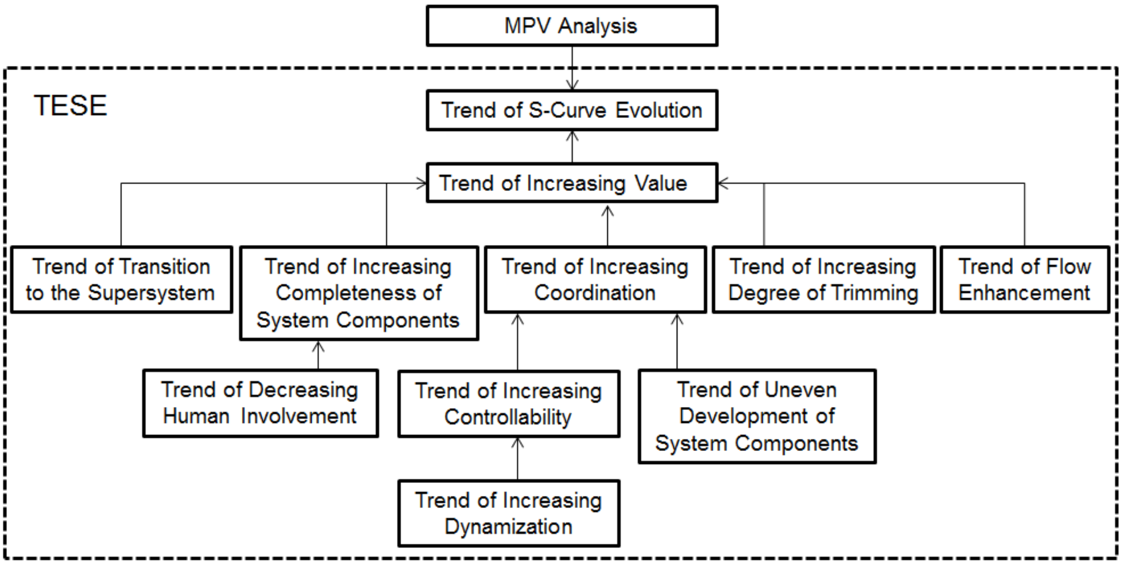

Figure 4. The main-trends and sub-trends of TESE at a glance according to the International TRIZ Association (2014), also with the superior MPV-Analysis

TESE is separated into two main-trends and several sub-trends. The first main-trend is the *Trend of S-Curve Evolution*, applied through the *S-Curve-Analysis* which was introduced in the previous chapter. The second main-trend is the *Trend of Increasing Value*. It describes the driving force behind every technological development. It is described as a "value of a product" defined by the ratio of functionality to cost. According to TRIZ, the goal of every technological development is to increase this value (International TRIZ Association, 2014). Most technical systems strive for low cost and high functionality (Ikovenko, 2015).
The principle of ideality for a system can be phrased after Chechurin (2015) as: The ideal system is the absence of the system, but its function is performed. This principle is helpful to understand the working principle of the underlying product.
Five sub-trends are subordinate to these two main-trends (see Figure 4): (1) *Trend of Transition to the Supersystem*, (2) *Trend of Increasing Completeness of System Components*, (3) *Trend of Increasing Degree of Trimming*, (4) *Trend of Flow Enhancement* and (5) *Trend of Increasing Coordination*. Some of them have further sub-trends, so called sub-sub-trends, which further specify these trends.
Our approach is based on following TRIZ literature: TRIZ manual form International TRIZ Association (2014), Adunka (2013), and San (2014). The approach of applying the TESE sub-trends can be described as such:

- Go over the given sub-trends in the literature and understand them.
- Read the examples how other technical systems evolved along sub-trends.
- Try to transfer the sub-trends and ideas to your own problem.

This approach supports to overcome innovation-barriers and find concrete solutions for the concrete problem, after learning about abstract solutions for abstract problems (see Figure 1). In Figure 5 we illustrate the procedure by the exemplary application of the *Trend of Increasing Dynamization*. Technical systems evolving along this trend run through the following states: First the system is monolith, over time, it becomes a joint-system and in the last phases, it becomes a powder, liquid, gaseous or even a field system. The technical system "toothbrush" ran exactly through those phases. The first toothbrushes were monolith and their handlebar was rigid. A next evolution showed a toothbrush which could be folded in the middle. Another one showed an elastic handlebar-collar for better cleaning results. And looking at nowadays toothbrushes, they work with ultrasonic technology; it therefore evolved into a field-system, the last stage of its successful evolution. (San, 2014)

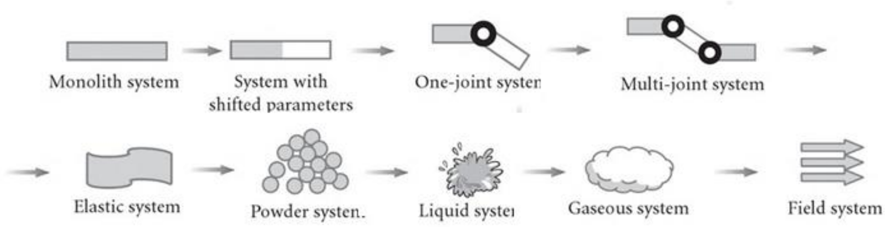

Figure 5. This shows how technical systems evolve along the Trend Of Increasing Dynamization according to San (2014)

3 METHODOLOGY FOR PRACTICAL PROBLEM SOLVING: APPLICATION OF TRIZ METHODS

3.1 Bridge between theory and practice

The following chapters show how the authors applied the TRIZ methods within the project work with and industrial development partner. The goal was to find solutions and create new concepts for future household appliance. The project work followed the five steps presented in chapter 2.1.

3.2 Step 1: MPV-Analysis

To figure out the MPVs for a certain product or technical system, it is important to perform studies as a first step, e.g. customer surveys or market research. For the given problem a big customer study was conducted by the household manufacturer itself, including eight countries and overall 8,000 people. Herein the customers were asked about their demands and dissatisfiers for this certain household appliance in the kitchen. Demands are proportional to "important" and dissatisfiers are proportional to "unsatisfied" in the definition of an MPV. After interpreting the data with the two analogies, we found the following MPVs:

- *(Operating) Noise*: Customers complained about the high noise level of the product.
- *Drying Result*: No remaining water on all components; for customers remaining water on inserted pieces and on the product is very annoying.
- *Water Consumption*: Optimization without compromises on hygiene and cleaning results; it is important for customers to save money and water when using the product.
- *Speed*: Time for cleaning and drying cycle; a faster process is desirable for customers.

3.3 Step 2: Evaluation of MPVs

In the second step, information about the MPVs regarding the metrics had to be found. For the metric *Performance* it is possible to review old product brochures or the internet. For *Number* and *Level of Inventions*, patent databases have to be scanned. For *Profitability* annual reports provide useful information.

In our case, it was possible to analyse the MPVs regarding their metrics to allocate them on *S-Curve*s. We illustrate the application on the example of *Noise*:

Each metric is subdivided into four phases like an *S-Curve*. For the metric *Performance*, old data-sheets reaching from the year 1970 until the present were evaluated. Afterwards the *Performance* for *Noise* was plotted over time (45 years) (see Figure 6). If the curve of *Performance* over the course of its whole lifetime is compared to the curve now, it is possible to see that *Noise* is for *Performance* in phase 3 because the *Performance* level is stagnating. The same was done for *Number of Inventions*. The patent-research gave a distribution over the last years. Compared to the curve of the lifetime metric it can be seen that regarding the rise of numbers of inventions this metric is also in phase 3. Unfortunately no data were found for the other two metrics. However, since the metric *Performance* and the metric

Number of Inventions are both located in their phase 3 it leads to the conclusion that the MPV *Noise* is overall also in phase 3 for its *S-Curve*, Maturity. Figure 6 shows the courses for the four metrics and the *S-Curve* on the upper half. The crosses indicate the resulting phase, the question mark indicates that no data were found, hence no phase. The lower part shows the underlying data and the result for the *S-Curve* phase Maturity.

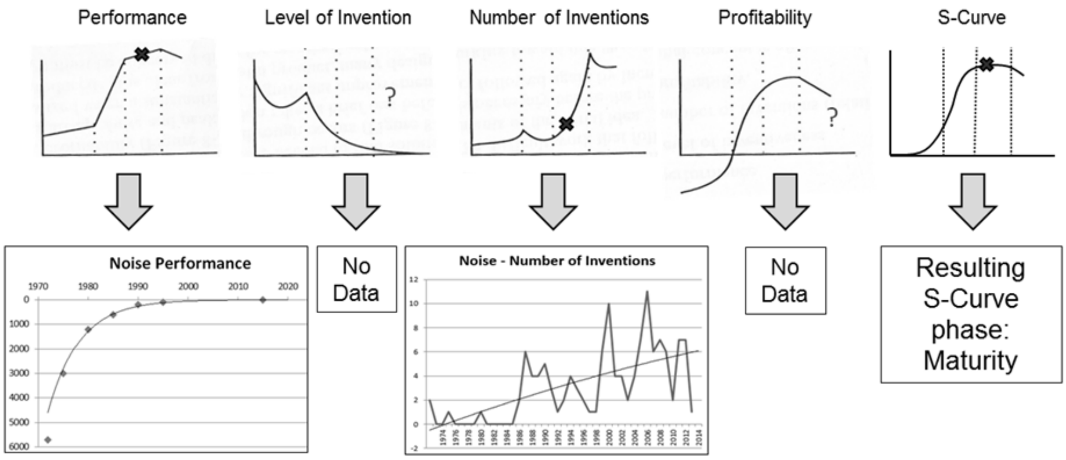

Figure 6. Overview over the applied metrics for the MPV Noise. Courses according to Terninko et al. (1996)

Finally, we identified the following life-phases for the four MPVs given in Table 1.

Table 1. The four found MPV's and their phase numbers and phase names

MPV:	Phase number:	Phase name:
Noise	Phase 3	Maturity
Drying Result	Phase 2	Infancy Growth
Water Consumption	Phase 3	Maturity
Speed	Phase 4	Retirement

3.4 Step 3 and 4: S-Curve-Analysis and identification of useful sub-trends

The pervious chapter showed how we localized the MPVs on the *S-Curves* with the help of metrics. However, it is not possible to do this "on the spot", but it is possible to allocate it in an entire phase. The resulting *S-Curve* for one MPV *Noise* is depicted in Figure 7. It could be done exactly the same for the other three MPVs.

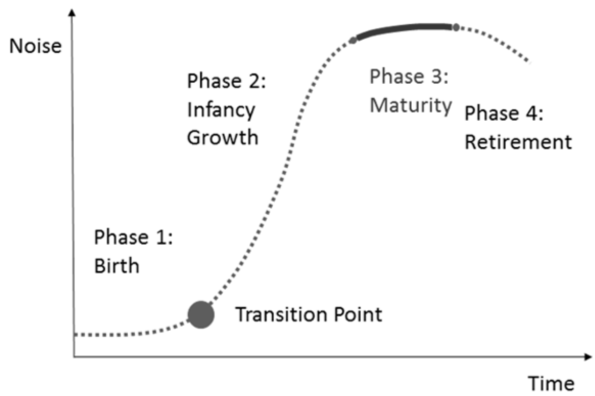

Figure 7. The resulting S-Curve display the allocated life-phase for the MPVs Noise of a household appliance in the kitchen (own figure)

Not only do we now know in which phase the MPV is, but the phase also gives suggestions about which sub-trend could lead the most successful to a solution of the problem (Adunka, 2013; Ikovenko, 2015).

This represents step 4. For example, the following trends are recommended for phase 3 maturity: *Trend of Transition to the Supersystem* and *Trend of Increasing Degree of Trimming*.
However, all sub-trends can be applied to generate ideas for the given problem. Chapter 4 outlines step 5 of the chosen approach. In addition, some solutions of the project work are highlighted.

4 RESULTS - FINAL IDEAS FOR FUTURE PRODUCTS

4.1 Step 5: Application of the identified sub-trends

Including the above-mentioned method we developed a total of 44 ideas within approximately two months of fulltime study. In this paper we highlight three final results which are presented in the following. Each of them show the application of step 5.

4.2 Example for improving MPVs #1: Trend of Increasing Dynamization

The sub-trend *Trend of Increasing Dynamization* has the sub-sub-trend *Dynamize Design.* A technical system is able to run through the following phase-transitions over time to further follow this trend: monolith system, system with shifted parameters, one-joint system, multi-joint system, elastic system, powder system, liquid system, gaseous system and field system (see Figure 5).
We transferred this trend into the operating mode of the household-appliance. In the past and in the present it has been mostly working with water. Following the sub-sub-trend *Dynamize Design* the next step would be to change the substance of functionality. The two resulting possibilities are a gaseous system or a field system. To do so, carbon dioxide, dry ice or even ultrasonic could be used. This would of course effect the MPV *Water Consumption*, but also the other three MPVs would improve. It would lead to an entirely new technology of this kitchen-appliance.

4.3 Example for improving MPVs #2: Trend of Transition to the Supersystem

The sub-trend *Trend of Transition to the Supersystem* has the sub-sub-trend *Parameters differ stronger*. One example is a ventilator which could have a different number of rotor blades or even a differentiation in form, colour or size of rotor blades. (San, 2014)
In the first step regarding this sub-trend, the main-function of the system is stated. For the underlying product the main-function is this: "The kitchen appliance fulfils action to objects". In the second step, the object should be changed. This means that the kitchen appliance fulfils its action not only for the currently given objects, but to any other object of the supersystem, the kitchen. Other items could be used, such as fruits, vegetables, tools, sponges etc. In the third step, the sub-trend could be used further by also changing the action of the kitchen-appliance. Other functions, found in the supersystem kitchen, are heating, cooling, cooking etc. This gives new ideas as to how and what to use for this product. The main advantage would be lower *Water Consumption* and of course saving time (*Speed*).

4.4 Example for improving MPVs #3: Trend of Increasing Dynamization

The same trend was applied as in example #1. This idea shows that the door to open the product could be designed as a multi-joint system. This means the door can be opened fully or only the upper half. This makes the usage of the product much easier and saves time. The *Trend of Decreasing Human Involvement* could be implemented in combination. With this concept, the user should be relieved ergonomically by having less interaction with the product. A small button could be implemented which opens the door automatically. Or even further, a gesture-recognition could be used to detect the user while he would like to open or close the door.

5 SUMMARY AND CONCLUSION

5.1 Summary of the project

This paper showed how to create new concepts in an industrial product development project with the help of TRIZ methods which was the aim of the project.
In the first step, we gathered knowledge about the product in the first step. The world-wide acting company behind the project provided a lot of data and studies about the product.
We started with a *MPV-Analysis*. The evaluation of a big customer study led to the following four MPVs: *Noise*, *Drying Result*, *Water Consumption* and *Speed*. Those were continued to use for having an *S-*

Curve-Analysis. This analysis is the first trend out of TESE (*Trends of Engineering Systems Evolution*), the *Trend of S-Curve Evolution*. This trend helps to allocate MPVs in their current life-phase (Altschuller, 1979). To do so, metrics help to analyse the MPVs. These are: *Performance*, *Level Of Invention*, *Number of Inventions* and *Profitability* (Terninko *et al.*, 1996). After evaluating the metrics, the results of the four MPVs on *S-Curves* are: *Noise* in phase 3 (Maturity), *Drying Result* in phase 2 (Infancy Growth), *Water Consumption* in phase 3 (Maturity) and *Speed* in phase 4 (Retirement).
The allocation of an MPV in its life-phase of an *S-Curve* provides information about its development over time and gives recommendations in which direction a MPV should be further developed. Those recommendations are given as TESE sub-trends which could be applied to find new innovations for the product. (Ikovenko, 2015; Litvin, 2011; Adunka, 2013)
Subordinate to the first main-trend of TESE, the *Trend of S-Curve Evolution*, is the *Trend of Increasing Ideality* and nine more sub-trends. Those help to follow the TRIZ typical approach of abstraction. In order to find a solution to a concrete problem, TRIZ abstracts the problem, gives an abstract solution which should be transferred to find a concrete solution. With this approach, we generated 44 new conceptual ideas for a household appliance for the kitchen, using the TRIZ method TESE sub-trends.
As a result of this paper, TRIZ helps to:

- Evaluate MPVs for a technical system.
- Allocate MPVs in their life-phase on *S-Curves.*
- Identify trends for MPVs and deriving recommended actions.
- Find solutions to problems using sub-trends in abstract areas (TESE).
- Generate ideas directed and save time.
- Develop innovations which follow a trend-forecast.

In the end, these concepts will help the world wide acting household appliance producer to develop future kitchen appliance.

5.2 Conclusion and Outlook

Within this project, we came upon some challenges. This chapter outlines how we coped with them. Additionally, we give an outlook what future research can be done within TRIZ and an industrial development.
As mentioned before, not all metrics are evaluable for a private person, outside a company. It is hard to find the right information; or you simply do not get it, for example the profitability of a certain subsystem of a product. But within this study, the company helped to gather important information, to evaluate most of the metrics. For a company, it is helpful to request the company intern patent division for assistance.
Furthermore, the chosen approach was very time-consuming. This project lasted six months, mostly one person was working full time on average. The outcome was four final concepts. If more people work longer on a specific problem, a more detailed and developed result is expected.
Many ideas could be gathered with the help of TRIZ. It is helpful to collect them clearly arranged in a booklet, in order to keep track. It helps to sort the information for each idea. This was done in this project. For every idea, we provided the following information in the booklet: Concept number, name of concept, affected MPV, affected component of the home appliance, description and sketch of the concept, estimation about feasibility and applied sub-trend.
In this paper we used some German sources; this is because some excellent research was done by German TRIZ applicants in the last few years. In the past and present, many books were published in German explaining the application of TRIZ methods.
Chapter 4 shows that the recommended sub-trends are no guarantee or a limitation for the only sub-trends that help to find solutions. In this work, the sub-trend *Trend of Increasing Dynamization* was used the most, despite the fact that it was not recommended. Further research could evaluate, why some sub-trends help, despite them not being recommended.
For the MPV *Speed,* an interesting contradiction was found: it was not possible to allocate the MPV *Speed* clearly. The metric *Number of Invention* leads to phase 1 and *Performance* to phase 4. The reason for the divergence is a European wide law which was introduced in the 1990s. The law provides a tightening of energy consumption. This results in a decline of the parameter *Speed*. The introduction of the law led to a "compression" of the *S-Curve* which results in a kind of "unnatural" development.

Finally, the MPV *Speed* was allocated in phase 4 which shows that the law forced the parameter to jump directly into phase 4 Retirement.

Systematic procedure within the process of inventing is not always easy (Jänsch, 2006). There are many barriers to overcome; time, staff and resilience are necessary components. Our overall conclusion of the project is that TRIZ is a powerful methodology for helping to invent. Even within an industrial framework, problems could be solved, and ideas with a promising future were developed.

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